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DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Filter-type Face Masks

We, MINNESOTA MINING AND MANUFACTURING COMPANY, of 900, Bush Avenue, Saint Paul 6, Minnesota, United States of America, a Corporation organised under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described, in and by the following statement:—

This invention relates to a filter-type face mask having a rounded preformed moulded cupped shape and provides a new type of surgical and hospital mask that meets the stringent requirements for such usage, as well as a new type of mask for industrial workers exposed to dusty or misty environments.

In the face mask according to the invention the entire body is a resilient moulded seamless nonwoven unified fibrous microporous filter membrane capable, on being deformed, of returning to its original shape, weighing not more than 10 grams and having an area in the range of 20 to 30 square inches. The cupped shape is contoured so as to stand out from the face of the wearer in substantial spaced relation and make a snug resilient low-pressure marginal contact over the bridge of the nose and across the cheeks and under the chin. The filter membrane is formed of a compacted moulded porous layer of randomly interlaced staple textile fibres which are coated and unified by a rubbery water-insoluble fibre-bonding sizing agent so as to provide a microporous membrane that is functionally effective as a filter and yet permits of comfortable breathing and speaking, the air flow pressure drop therethrough being not over about 0.05" water when measured at a steady flow rate of 30 litres per minute as herein described.

The one-piece shaped-fabric porous mask is thus large enough to fit over the front of the face below the eyes in a nonconstricting spaced-away manner which permits of

easy breathing and speaking and avoids any sensation of suffocation. It is of such lightness, flexibility and resiliency that a single model can be designed and sold which readily conforms to any reasonably normal face to provide a good and comfortable fit. The mask contacts the face only at its margin. It can be comfortably retained in place by a light elastic band that is positioned around the head.

The mask has sufficient stiffness and moisture resistance to retain a cupped shape on the face and not collapse or wilt during breathing, even on extending wearing for a period of hours. An integral pliable metal nose strip secured at the top edge of the mask, permits the wearer by use of thumb and forefinger to readily conform the upper margin of the mask over the bridge of the nose and the adjacent facial regions below the eyes, so as to assure a good fit and prevent warm exhaled moisture from leaking through and fogging the wearer's glasses. The mask has a size and shape which precludes objectionable interference with the wearer's field of vision in doing his work.

Among materials suitable for carrying out the present invention are those which are described in our Patent No. 966,855. Likewise the methods described in that Patent are also applicable in forming the face masks of the present invention.

The accompanying drawing illustrates this mask as worn upon the face in the manner described above.

As shown, the mask proper consists solely of a resilient moulded rounded cupped-shape microporous membrane 1 capable, on being deformed, of returning to its original shape. It is securely held in place on the face by a light elastic band 2 passing around the head, the ends of the band being fastened to opposite side edges of the mask in any suitable way during manufacture (as by stapling). The mask is contoured such as to be fittable and

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retainable against any normal face with a snug low-pressure marginal contact between fabric and skin; the mask otherwise standing out from the face (including the tip of the nose) in substantial spaced relation but not so as to hamper the field of vision. The lightness of the mask and its fit to the face permits of a light stretchy narrow head band exerting only a light tension, which facilitates putting on and adjusting the mask, and quickly and easily removing it whenever desired. A narrow pliable aluminium nose strip 3 is adhesively bonded to the mask at its upper edge, permitting conformation over the bridge of the nose and below the eyes as shown. The margin of the mask is free to flex such that by simple manipulation the margin will contact the face across the cheeks and under the chin to make a snug fit. The springy mask is contoured so that the fabric margin flares to meet the face at an acute angle which provides a sealing relationship that is retained during wearing and does not produce discomfort, owing to the area of contact and the light face pressure.

The unified non-woven mask fabric preferably weighs not over about 5 grammes and consists of a suitably contoured compacted moulded or shaped porous layer of randomly interlaced staple textile fibres (for example, man-made organic fibres of about 1/2 to 2 inch length) which is unified by impregnation with a rubbery water-miscible fibre-bonding sizing agent (for example, an acrylic textile sizing latex) which thinly coats the individual fibres and bonds them together at their crossing points while retaining a sufficiently porous fabric condition. The sizing coating on the fibres preferably includes a wetting agent so that aqueous droplets trapped or condensed by the mask will be absorbed by capillary action and film out on the sized fibrous surfaces, the water subsequently evaporating. Breath-borne droplets maintain the fibres in a slightly damp state during the use of the mask and this appears to improve filtration efficiency and to aid in preventing the building up of electrostatic charges. The air flowing through the mask facilitates evaporation and prevents it from becoming excessively damp. This unified fabric provides a light, tough, flexibly resilient, moisture-resistant, microporous fibrous membrane of cupped shape—having a vast number of closely-spaced inter-filar passageways or pores throughout its entire area. The mask does not become electrically charged in use, thereby avoiding sparking hazards. This construction permits of complete mask devices weighing less than 10 grammes and even less than 5 grammes.

The mask has an area in the range of about 20 to 30 square inches and most of this entire area is employed as the functional filter area for breathing through. The large functional filter area (which is much larger than the filter

area of certain other types of masks), in combination with the location on the face and the substantial spacing from the nose and mouth of the wearer, makes possible the above-mentioned comfort features in a mask which provides the desired filtration effectiveness.

The traditional surgical mask utilizes four or more layers of gauze and is held in direct contact with the face, overlying the mouth and nose. The resulting facial contact and constriction of the mouth and chin interferes with normal breathing and speaking. Particularly objectionable is the facial discomfort and warmth, and the feeling of suffocation, induced upon lengthy wearing of such a mask. Some surgeons are made so uncomfortable and become so distracted in the course of a lengthy operation that they cannot resist pulling the mask down so as to liberate their nose and nostrils, thereby of course partially nullifying the purpose of the mask. The conventional mask is not lint-free and this results in the ejection of bacteria-carrying lint particles, as well as in inhalation of lint by the wearer. The present mask avoids these faults and can be worn by the surgeon for many hours with tolerable comfort, and it provides better filtering efficiency.

An important feature of the present type of mask is that it can be manufactured with uniformity on a mass production mechanised basis and at a low enough cost to permit of sale at a price that warrents disposing of the complete mask device after a single period of use. Thus these masks can be sold to hospitals as a "throw-away" type of mask—eliminating a great deal of the bother heretofore associated with masks. The present general practice is to re-use the gauze masks several times (involving collecting, washing and later sterilising the masks after use). One-time usage followed by prompt complete sanitary disposal could contribute to reducing the chances for the spread of infectious agents in hospitals.

The preferred moulded one-piece seamless mask of the present invention can be autoclaved or gas sterilised, and re-used, if desired.

The aforesaid benefits would be of no avail if the mask were incapable of effective filtering action for the intended hospital, surgical or industrial usage.

Experimental evidence, however, demonstrated that the relatively simple and inexpensive type of mask of the present invention is in fact acceptable for such usages. The surgical mask has been studied and used by eminent surgical authorities and has been found by them to be a superior substitute for the well known gauze mask, providing a remarkable technical advance worthy of general adoption.

An illustration of the filtration superiority

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was provided in tests in which sterile blood-agar petri dish plates were exposed at a distance of 12 to 14 inches (30 to 35 cm.) from the mouths of masked and non-masked test subjects, for an exposure period of two minutes. The person positioned his head horizontally above the petri dish and simulated a series of sneezes by explosively ejaculating the syllable "cheo" every six seconds. This test produces more atomised moisture droplets and bacteria colonies in a given time than are produced by breathing, speaking or coughing; and this procedure provides good evidence of comparative efficiencies for hospital usage. The typical air-borne oral organisms deposited on the plates were incubated and the colonies counted. When the subjects wore no mask, the average number of colonies was 461. In the case of subjects wearing the hospital mask, the plates developed an average of only 2 colonies, indicating a 99.5% removal of the air-borne organisms. In contrast, there was an average of 149 colonies when these subjects wore a standard new four-ply gauze mask, indicating a 68% removal.

Tests also indicate that the mask of the instant invention closely retains its initial efficiency for at least eight hours of wearing and is much superior in this respect to conventional gauze masks.

Another illustration of filtration efficiency was provided by a test in which it was found that the mask was about 85% efficient in removing dust from respired air, when worn by persons in a room in which a cloud of magnesium carbonate dust had been dispersed, this fine dispersed dust having a mean particle size diameter of about 3 microns, 85% of the dust particles having diameters of less than 5.0 microns, and 50% having diameters of less than 2.0 microns.

The key to this unpredictable success resides in the unified reticular fibrous microporous membrane structure and the large cupped-shape filter area that is provided. This arrangement results in a substantial volume of air between the face and the mask. Under conditions of reasonably normal breathing, the requisite volume of inhaled and exhaled air can pass through the interfilar passageways provided by this large filter membrane, with only a slight pressure drop and at a slow velocity, not only making for breathing ease but permitting excellent entrapment of micro-organisms, mist and spray droplets, and dust particles. Most of the filtering action results from impact and diffusion as the air finds its way through the tortuous passageways defined by the layer of randomly interlaced fibres, the particles sticking to the fibres. The slight pressure drop also precludes collapsing of the cupped-shape fabric mask during inhalation, despite its lightness and flexibility.

Heretofore it has been a common assumption

that a relatively high pressure drop is necessarily associated with really good face mask filters as otherwise the filter would be too permeable to air-borne particles and micro-organisms. A high pressure drop is of course incompatible with breathing comfort. The discovery that the face mask of the present invention, which permits of a very low pressure drop and of breathing comfort, has an efficiency adequate for a superior surgical mask, was thus all the more surprising on this account.

A typical preferred mask, having a filter fabric weight of 3 grammes and an area of 24 sq. in. (155 sq. cm.), permits of a pressure drop ranging from about 0.02 in. (0.5 mm.) water for an air flow rate of 8 litres per minute up to about 0.07 in. (1.8 mm.) for a flow rate of 50 litres per minute; corresponding to the breathing requirements of average persons engaged in work ranging from sedentary to moderately heavy. (As measured on a laboratory test device using different air flow rates through the mask; the pressure drop across the mask being measured by a precision inclined-tube water manometer. In this test the mask is taped to a metal holder and fastened (convex side in) to the downstream end of a sheet metal pipe having a length of 15 in. (38 cm.) and a diameter of 6 in. (15 cm.). The mask is fastened with its convex side (i.e. that normally towards the face) towards the metal pipe. The manometer is connected to a nipple in the pipe wall located approximately one inch (2.5 cm.) from the tip of the mask. The air-flow into the other end of the pipe is held at a desired constant value by means of a flowmeter). A mask pressure drop not exceeding approximately 0.05 in. (1.3 mm.) water when measured at a steady flow rate of 30 litres per minute is preferred. This steady air-flow rate for test purposes, corresponds approximately to the average flow when a wearer is breathing with a peak air-flow rate of 90 litres per minute, which is the requirement for an average person doing moderate work. The mask of the instant invention has been found in practice to have a sufficiently low resistance to breathing to permit of comfort even when worn by a person doing moderately heavy work. This is of further importance because any undue resistance to breathing results in the body attempting to compensate by more frequent breaths or by deeper breathing, disturbing the usual rhythm; and if the resistance is too great the body becomes excessively fatigued due to deprivation of adequate oxygen. Moreover, a small but long-continued reduction in the oxygen intake can induce a marked feeling of fatigue and a significant interference with work requiring extreme dexterity and concentrated attention and thought, a matter of much importance to a surgeon performing a delicate and

difficult operation over a period of several hours.

It will be apparent from the entire foregoing discussion that the novel mask of the present invention possesses quite a few desirable characteristics; and in particular that it is the combination of important features obtainable in a simple, lightweight, comfortable, efficient, low-cost mask which makes the present contribution so useful.

The moulded non-woven fibrous microporous filter can be made up by various techniques whereby a suitably shaped layer of interlaced staple textile fibres is formed and is impregnated with a suitable rubbery sizing agent to unify the fabric and coat the fibres; appropriate selections and proportions being employed to obtain a product having the requisite combination of physical properties.

But, as has been emphasized, this invention is of particular value because it permits of low-cost manufacture of the complete face masks. The following description will, therefore, be directed to explaining the novel way of accomplishing this low-cost manufacturing which has been discovered and which has been successfully utilized in making the preferred masks of the present invention.

In general terms, the non-woven cylindrical-shape microporous fabric membrane is formed by first moulding a fluffy carded sheet of initially unbonded interlaced staple fibres which includes a substantial proportion of unplasticised undrawn (amorphous) thermoplastic polyester binder fibres, the balance being structural fibres which remain hard and non-tacky in the thermo-softening range of said undrawn polyester fibres. The fibres preferably have a length of about 1 to 2 inches (25 to 50 mm.) and the proportion by weight of the undrawn polyester fibres is in the range of about 30 to 50%, the sheet having a weight in the range of about 200 to 400 pounds per thousand square yards. This fluffy dry fibrous sheet is shaped over a gang of heated aluminium male moulds maintained at a temperature in the thermosoftening range of said undrawn polyester fibres, the fibrous state permitting of conformation to the moulds. A gang of closely-spaced moulds is used so that a substantial number of masks can be made together.

This shaped fluffy sheet is then promptly subjected to uniform soft-pressing against the heated moulds to compact and unify it to a stable moulded shape precisely conforming to the male moulds; the undrawn polyester fibres becoming fused together at their mutual crossing points without any mashing of fibres occurring. This pressing can be effected by an overlying stretchy rubbery non-adhering blanket (such as a silicone rubber sheet), the intervening air being removed by suction to permit atmospheric pressure to push and

shape the blanket against the fibrous sheet on the moulds and thereby compact it. The suction is then rapidly released and the blanket promptly removed and the hot moulded fibrous sheet is immediately separated from the moulds. There is no sticking to the heated gang of aluminium moulds and the sheet retains its shape during the further processing.

These important factors are made possible by the unique nature of the undrawn polyester fibres. During the moulding operation, these fibres first soften and become tacky and readily fuse together at their crossing points. Then, during the continued heating, they become crystalline and harden and stiffen, to provide a three-dimensional reinforcing and stiffening network, and lose their tackiness so that there is no adherence to the hot aluminium mould surfaces. This transformation results in a sufficiently-unified shape-retaining moulded sheet which can be lifted away without cooling and without distortion of shape. High-speed production is made possible in this way of moulded masks having a highly uniform predetermined shape and a uniform fibrous structural formation.

The moulded sheet supported in horizontal position, convex side up, is then saturated with an aqueous dispersion of water-insoluble rubbery acrylic polymerizing latex (or equivalent) which is applied from above in dribbling fashion through dispensing heads containing small holes. Saturation is facilitated by the wicking action of the compacted fibrous structure. A wetting agent is preferably included in the latex dispersion to facilitate saturation, and also to provide readily wettable fibrous surfaces in the mask product for reasons previously mentioned. The concentration of the latex solids is chosen so that the fibres will be coated, and interbonded at their crossing points, and the desired microporous structure provided in the product. The moulded fibrous sheet fibres have sufficient unification and stiffness to resist the moderate forces involved during this stage and the subsequent drying stage, before the fully-unified rough state is achieved; so as to avoid interim distortion.

After drying by passing through a hot air oven, the moulded sheet is ready for cutting out of the individual shaped masks and trimming or finishing moulds to provide the desired edge configuration. The aluminium nose strip is adhesively bonded to each mask, and the stretchy head cord is stapled at each end to opposite side edges. The completed masks are now ready for packaging.

Consistent with the foregoing general description the following details relate to the presently preferred manufacture of surgical masks having the qualities previously mentioned.

A fluffy blended-fibre web weighing about

250 lbs. per thousand square yards is made up by mixing the different fibres and forming a carded-type batt by use of a garnett machine or the like. A "Rando-Webber" machine (sold by Curlator Corp., Rochester, New York) can be employed directed and interlaced into a loose fluffy web wherein the various types of fibres cross over and under each other so as to be held together in three dimensions, the fibres being able to shift about in the subsequent moulding operation to form a uniform layer having the desired cupped shape.

The fibre mixture consists (by weight) of 40% undrawn (amorphous) polyester fibres of 6-8 denier size and 1 1/2 inch length, 20% of the conventional drawn type of polyester textile fibres of 1 1/2 denier size and 1 1/2 inch length, and 40% of viscose-rayon fibres of 3 denier size and of 1-9/16 inch length. All fibres are unplasticised. This mixture of fine, medium and coarse fibres is well-suited to making the present type of mask. As is well known in the textile trade, the conventional drawn polyester staple fibres are chopped from continuous filaments formed by melting, spinneret extruding, and drawing (stretching), a high molecular weight polyester of a dihydric alcohol and a dicarboxylic acid; exemplified by the textile fibres sold by the du Pont company under the trade mark "Dacron", and understood to be made from a polyester of ethylene glycol and terephthalic acid. The undrawn (amorphous) polyester fibres are produced in the same manner except that the drawing operation is omitted. The latter fibres have an inherent

wide softening temperature range below the temperature at which they fluidify or melt, which in which the thermosoftened fibres can be autogenously interbonded at crossing points by application of light pressure, the fibre identities being retained. This initial softening temperature range is below the narrow melting range of the corresponding crystalline drawn fibres. For instance, staple fibres chopped from the undrawn polyester filaments produced intermediately in the manufacture of "Dacron" fibres, have a thermobonding softening temperature range of approximately 200 to 450°F. whereas the regular "Dacron" fibres of the same chemical composition have a melting point of approximately 480°F. and are not soft and capable of autogenous interbonding with each other in said 200 to 450°F. range.

The mould table includes 18 cast aluminium male moulds which are maintained by internal heating at a surface temperature of about 350°F. The total contact time during moulding is about 15 seconds.

The moulded sheet is placed on a moving belt having openings therein to facilitate draining and drying, and is saturated from above by dribbling on an aqueous dispersion of acrylic textile sizing latex having a latex solids content of approximately 6%, adapted to produce a pickup of acrylic polymer of approximately 50% by weight (dry basis) relative to the fibre weight. The following formulation employing commercially available materials has been advantageously used (all parts by weight):

	Parts
Polyethylacrylate latex dispersion (46% solids)	40.5
(Preferably copolymerized with a small proportion of methacrylic or acrylic acid; for example, "Rhoplex B15" sold by Rohm & Haas Co.)	
Polymethylmethacrylate latex dispersion (38% solids)	18.0
(for example, "Rhoplex B85" sold by Rohm & Haas Co.)	
Wetting Agent of non-ionic alkyl aryl polyether alcohol type	0.2
(for example, "Triton X100" sold by Rohm & Haas Co.)	
(Triton is a Reg. Trade Mark)	
Rewetting agent of anionic sulphonated alkyl ester type	0.2
(for example, "Triton GR-5" sold by Rohm & Haas Co.)	
Sodium perborate (bleaching agent)	1.0
Fluorescent blue dye (optical bleach)	0.2
(for example, Du Pont's "paper white BP dye")	
Water (approximately)	351

The methylmethacrylate polymer is *per se* hard and thermoplastic and is used in minor proportion in blended combination with the ethylacrylate polymer (which is *per se* soft and rubbery) to obtain the desired degree of stiffness or rigidity in the moulded fabric mask so that it will not collapse during breathing. The rewetting agent is so called because it not only serves as a wetting agent in the aqueous impregnating dispersion but provides a dried mask product wherein the coated or sized

fibres are readily wetted by impinging moisture droplets.

The saturated sheet of masks is then conveyed through a circulating hot air oven heated to approximately 300°F. where it is dried.

The individual masks are separated and trimmed. These masks each weigh approximately 3 grammes and have an area of approximately 24 sq. in. and a thickness of approximately 15 mils. An elastic head band

5 of 3/32 in. width and 14½ in. length is stapled to each mask; and a pliable aluminium strip of 19 mils thickness and 3½ in. by 3/16 in. size, coated with a thermosetting adhesive, is positioned and bonded in place by heat and pressure. This design results in a complete mask device weighing approximately 4 grammes.

10 The measured pressure drop for these masks varies somewhat but is less than 0.05 in. water at an airflow rate of 30 litres per minute. Porosity measurements made on an Aminco-Winslow Porosimeter indicate an average total porosity of about 60%. Most of the filtering action is not by sieving but by impact and diffusion. The effectiveness of the mask results from the low pressure drop and the low airflow rate per unit of area through the large-area reticular fibrous layer structure.

20 The mask may be moulded or shaped so as to have a ribbed structure. In this way a cupped shape of greater rigidity can be obtained.

25 The fibrous layer may be thicker and have a less dense structure than in the above example. Fibres of very fine size (very low denier value) may be included in the fibre mixture so as to improve filtration efficiency as to fine dust particles encountered by industrial workers. Medicants and absorbents may be included in the mask.

#### WHAT WE CLAIM IS:—

1. A filter-type face mask suitable for surgical, hospital and industrial usage, having a rounded preformed moulded cupped shape, the entire body of which is a resilient moulded seamless one-piece nonwoven unified fibrous microporous filter membrane capable, on being deformed, of returning to its original shape, weighing not more than 10 grams

and having an area in the range of 20 to 30 sq. in., the cupped shape being contoured so as to stand out from the face of the wearer in substantial spaced relation and make a snug resilient low-pressure marginal contact over the bridge of the nose and across the cheeks and under the chin and the filter membrane being formed of a compacted moulded porous layer of randomly interlaced staple textile fibres which are coated and unified by a rubbery water-insoluble fibre-bonding sizing agent so as to provide a microporous membrane that is functionally effective as a filter and yet permits of comfortable breathing and speaking, the air flow pressure drop there-through being not over about 0.05" water when measured at a steady flow rate of 30 litres per minute as herein described.

2. A filter-type face mask having a pliable nose strip secured at the top edge adapted to permit the wearer to conform the mask to the bridge of the nose and adjacent facial region below the eyes, and having a light stretchy elastic head band whose ends are secured to opposite side edges of the mask and which is adapted to comfortably hold the mask in place on the face.

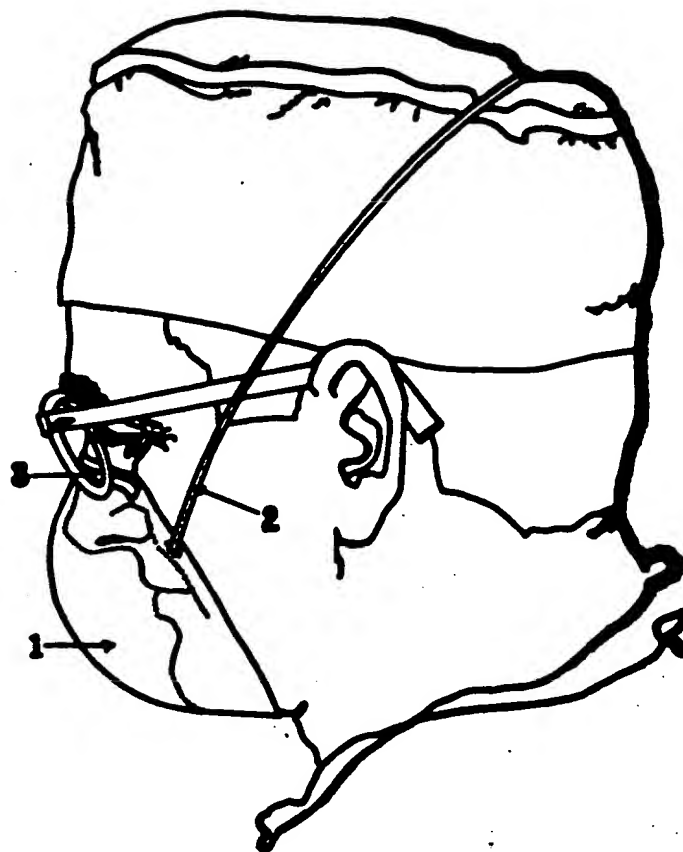
3. A filter-type face mask according to claim 1 or claim 2 in which the cupped shaped body has a flared margin.

4. A filter-type face mask according to any preceding claim having a weight of not more than 5 grams.

5. A filter-type face mask substantially as described herein with reference to the accompanying drawing.

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